

A Reusable, State-Based Guidance, Control and Navigation Architecture for Future Planetary Missions

Mission Data System (MDS) is a project at NASA's Jet Propulsion Laboratory to produce a reusable, integrated flight and ground software architecture, which will be adapted by future JPL planetary projects. The architecture is based on identifying the states of the system to be controlled, and on identifying methods to measure, estimate, model and control these states. States are controlled by goals, and the natural hierarchy of the system is employed by recursively elaborating goals until primitive control actions are reached.

Fault tolerance emerges naturally from this architecture. Failures are detected as discrepancies between state estimates and model-based predictions of state. Fault responses are handled either by re-elaboration of goals, or by failures of goals invoking re-elaboration at higher levels. Failure modes are modelled as possible behaviors of the system, with corresponding state estimation processes.

Architectural patterns are defined for concepts such as states, goals, and measurements. Aspects of state are captured in a state-analysis data base. Unified Modelling Language (UML) is used to capture mission requirements as Use Cases and Scenarios. Application of the state-based concepts to specific states are also captured in (UML), achieving architectural consistency by adapting base classes for all architectural patterns.

Within the Guidance, Navigation and Control domain of MDS, work has focussed in 3 areas:

- 1.) Reengineering and reimplementation of legacy Navigation systems within an object-oriented structure that is reusable from mission to mission and common between flight and ground systems;
- 2.) Identification of states and mission activities which are common across multiple missions;
- 3.) Exploitation of commonality between Attitude Control and Navigation functions, which have historically been separated in previous JPL missions.

These areas will be demonstrated on a simulated reference spacecraft and mission, and then adapted by customer missions. Early deliveries will have levels of autonomy similar to existing JPL spacecraft, in order to demonstrate the applicability of the state-based concepts. This architecture is expected to greatly simplify the implementation of existing levels of autonomy, and to provide the basis for significantly-increased autonomy in future deliveries. Studies are ongoing to determine the mission requirements for highly integrated attitude and trajectory control functions, leading eventually to "6-degree-of-freedom" control. These functions will eventually be implemented within the MDS architecture.

The first customer mission is Europa Orbiter, to be followed by Pluto/Kuiper and Solar Probe. Discussions are also ongoing to adapt MDS for Stellar Interferometry Mission and for control of the Deep Space Network.

First prototype demonstration will be in Nov. 1999, with subsequent deliveries of increasing capability leading to a delivery to Europa in Nov. 2001.